

Kansas Department of Health and Environment  
Report of Radiological Environmental Monitoring of the Environs Surrounding  
**Wolf Creek Generating Station**



July 2016-June 2017  
Division of Public Health, Bureau of Community Health Systems  
Radiation Control Program  
1000 SW Jackson St., Suite 330  
Topeka, Kansas 66612-1365

Kansas Department of Health and Environment  
Environmental Radiation Surveillance Report  
Wolf Creek Generating Station  
State Fiscal Year 2017

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## Introduction

Wolf Creek Generating Station (WCGS) is a pressurized water nuclear reactor capable of producing over 1,200 megawatts of electrical power. Located near Burlington Kansas, the plant is operated by Wolf Creek Nuclear Operating Corporation (WCNOC). The facility releases radioactive material to the environment in the form of liquid and gaseous effluents. This report details the results of surveillance of the environs surrounding WCGS conducted by the Kansas Department of Health and Environment (KDHE) from July 1, 2016 through June 30, 2017.

KDHE's Wolf Creek Environmental Radiation Surveillance (ERS) program began in 1979 in accordance with Kansas Administrative Regulation (K.A.R.) 28-19-81 with the initial selection of surface water sampling locations. The ERS program parallels (and partially overlaps) the WCNOC Radiological Environmental Monitoring Program (REMP).

The purpose of the ERS program is to detect, identify, and measure radioactive material and direct radiation released to the environment from the operation of WCGS. Data indicating the release of elevated levels of radioactive material will be used to determine the need for corrective and/or protective actions to protect the health and safety of the public.

The ERS program includes the following monitoring methods:

- Measurement of ambient external radiation levels using optically stimulated luminescence dosimeters
- Monitoring of radionuclides present in ambient air through weekly collection and laboratory analysis of continuous air samples
- Monitoring of radionuclides present in water, terrestrial vegetation, aquatic vegetation, fish, sediments, and soil through scheduled and random sample collection and laboratory analysis.

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## Results Summary

The most significant radionuclide present in surface water samples collected in the Coffey County Lake (CCL) is tritium ( $^3\text{H}$ ), a beta emitter. The highest  $^3\text{H}$  concentration measured in the Coffey County Lake during SFY 2017 was 12,764 pCi/l in September, 2016 at the CCL MUDS location. This maximum Coffey County Lake  $^3\text{H}$  concentration is 64% of the National Primary Drinking Regulation maximum contaminant level (MCL) of 20,000 pCi/l. *The water from the Coffey County Lake is not used as a drinking water source.* The average CCL surface water  $^3\text{H}$  concentration for SFY 2017 was 10,032 pCi/l, or 50% of MCL. Coffey County Lake is not approved for any aquatic recreation other than fishing. No  $^3\text{H}$  was found in surface water from the Neosho River during times where CCL flowed over the spillway.

All other non-CCL surface water and offsite ground water samples collected in the environs of WCGS during SFY 2017 indicated no radionuclides present attributable to the operation of WCGS.

Aquatic vegetation samples are the best indicators for monitoring the seasonal fluctuations of fission and activation product levels in the Coffey County Lake. No aquatic vegetation sample showed any nuclides attributable to WCGS operation. Four trending samples and six random samples were analyzed.

Sediment samples have been excellent indicators for the long-term buildup of fission and activation product activity levels in the Coffey County Lake. The highest fission product activity in sediments during SFY 2017 was 163 pCi/kg-dry  $^{137}\text{Cs}$  in a shoreline sediment sample taken in May 2017 from John Redmond Reservoir (JRR). No sediment samples showed any nuclides attributable to WCGS operation.

Airborne sample analysis indicated that no radionuclides attributable to the operation of WCGS were present above the lower limits of detection during SFY 2017.

Sample analysis of aquatic vegetation, terrestrial vegetation, soil, milk, grain, and vegetable samples collected in the environs of WCGS during SFY 2017 indicated no radionuclides present attributable to the operation of WCGS.

Samples of nine species of fish were taken from the Coffey County Lake during SFY 2017. Sample analysis of edible fish portions collected in the environs of WCGS during SFY 2017 indicated that no gamma emitters attributable to WCGS operation were present. The highest  $^3\text{H}$  concentration in tissue was 7,260 pCi/kg-wet found in a Blue Catfish sample taken from the CCL. Using an ICRP 30 dose conversion factor for ingestion ( $h_{E,50}$ ) of  $6.40 \times 10^{-8}$  mrem per pCi  $^3\text{H}$  ingested, a standard man consuming 21 kg/y of fish containing 7,260 pCi/kg  $^3\text{H}$  would receive a committed effective dose equivalent of 0.0098 mrem. The projected dose equivalent is far below the 100 mrem/yr regulatory limit for a member of the public.

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Data from direct radiation monitoring sites revealed no significant changes from preoperational data. The lowest direct radiation levels are found closest to the WCGS. The direct radiation levels on the Coffey County Lake baffle dikes at the 1,200 m exclusion area boundary are the lowest of any monitored site. The limestone used to construct the baffle dikes has a lower natural background radioactivity than the original soil present before the construction of the Coffey County Lake. This effect of construction on the terrestrial component of natural background radiation was noted on radiation surveys conducted around the WCGS site before bringing the initial fuel load on the site. The water from the Coffey County Lake also acts as an effective shield from terrestrial radiation that was present before Coffey County Lake filling.

The ratio of KDHE results to WCNOG results ranged from 0.83-.99. A summary of comparison data may be found in the Results Comparison Table.

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**Results Summary Table**

Type of Sample	Number of Sampling Stations	Total Samples Collected
Air (Particulate and Iodine)	5	520
Soil	5	5
Random Soil	10	10
Direct Radiation	31	248
Surface Water	4	32
Offsite Ground Water	6	24
Onsite Ground Water	3	9
Sediments	5	13
Random Sediments	16	16
Aquatic Vegetation	5	5
Random Aquatic Vegetation	6	6
Game Animals/Domestic Meat	1	1
Terrestrial Vegetation/Human, Animal Food	9	9
Random Terrestrial Vegetation/Human, Animal Food	10	10
Milk	2	8
Fish	2	27
<b>Total</b>	<b>117</b>	<b>943</b>

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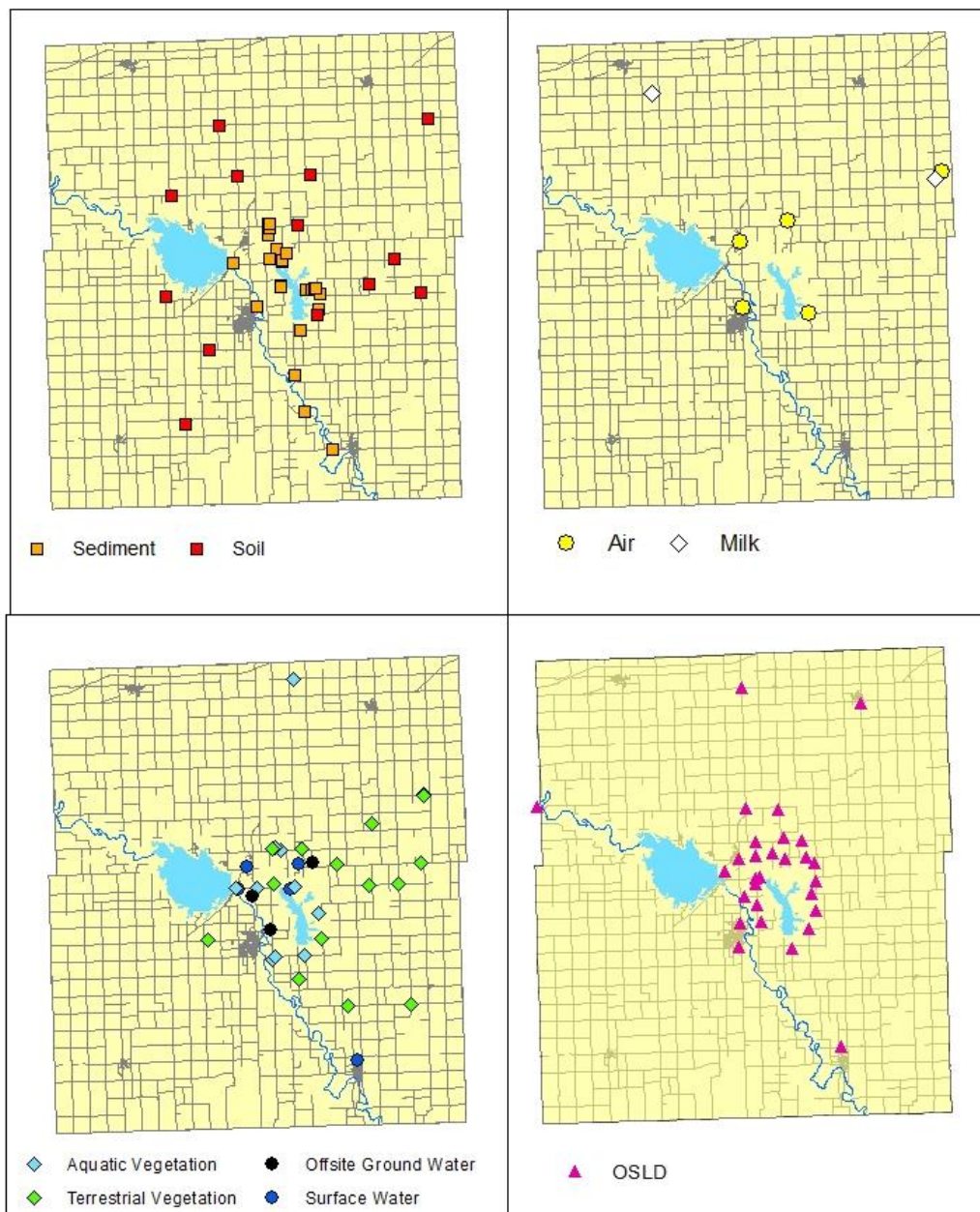
### Results Comparison Table

Description	Average	Standard Deviation	Minimum	Maximum	N
OSLD direct radiation, mR per 90 day quarter	17.6	1.98	11.4	21.2	124
Airborne particulate and radioiodine cartridge gamma isotopic analysis ( <sup>7</sup> Be) pCi/m <sup>3</sup>	0.152	0.044	0.016	0.249	52
Coffey County Lake Surface Water tritium ( <sup>3</sup> H), pCi/l (Spillway)	10,032.67	1037.87	8,337	11,253	9
John Redmond Reservoir, control (N-1) ( <sup>3</sup> H), pCi/l	<153	NA	NA	NA	9
Coffey County Lake MUDS ( <sup>3</sup> H), pCi/l	9,912.67	1,482.35	8,067	12,764	10
Neosho River Near LeRoy ( <sup>3</sup> H), pCi/l	<153	NA	NA	NA	4
New Strawn City Lake ( <sup>3</sup> H), pCi/l	<153	NA	NA	NA	1
Offsite ground water tritium ( <sup>3</sup> H), pCi/l (All Stations)	<152	NA	NA	NA	24
Onsite ground water tritium ( <sup>3</sup> H), pCi/l (Stations where activity was detected)	944.14	846.64	210	2416	8
Surface and Offsite Ground Water Gamma Isotopic Analysis	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any surface water or offsite ground water sample evaluated.				
Gamma isotopic analysis of soil, pasturage, garden vegetables, and grain.	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any soil, milk, pasturage, garden vegetable and grain sample evaluated.				
Maximum activity attributable to Wolf Creek Generating Station operation, pCi/kg					
Coffey County Lake Fish	<sup>3</sup> H, 7260 ± 200 pCi/kg (Blue Catfish)				
Comparison Of KDHE and WCNOG Results					
Analysis	Average Ratio of KDHE results to WCNOG results		Comments		
OSLD Direct Radiation	0.99		12 Collocated Sites		
Surface Water <sup>3</sup> H	0.95 (N=12)		CCL Spillway		
Sediment gamma isotopic	0.83		<sup>137</sup> Cs, when detected		
Fish <sup>3</sup> H	0.92		CCL		
Onsite Ground Water <sup>3</sup> H	0.97		AUX, West-ESW-West		



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Sample Location Maps



## Sample Results

### Inhalation Pathway

#### Air Particulate and Iodine

Air samples were collected weekly. Five air-sampling sites, four of which are collocated with WCNOG, have continuously operating low-volume air samplers contained in a fiberglass housing mounted on utility poles approximately one meter from the ground. Air samplers are located at Sharpe, KS (A-1), east of the Coffey County Lake dam (H-1), Burlington, KS (L-1), New Strawn, KS (P-1), and near Westphalia, KS (D-2). The collocated sites include the highest calculated annual average ground level relative concentration (X/Q) area at Sharpe, the highest calculated annual average ground level relative deposition (D/Q) area at New Strawn, and a control location near Westphalia. An average flow rate of 30 liters per minute is used with 47 mm diameter glass fiber particulate filters and 5 percent triethylenediamine (TEDA) impregnated carbon cartridges for radioiodine activity (the major isotope of concern is  $^{131}\text{I}$ ). TEDA binds the iodine chemically and reduces losses from desorption.

Field assay of each particulate filter was performed at the time of collection. The particulate filter was counted using a thin window GM 'pancake' detector (Ludlum Model 44-40 or equivalent) and a count rate instrument. A sample net count rate of greater than two times the net count rate of the current control (Near Westphalia, D-2) air sample indicates a potential anomaly and the filter is then flagged for individual gamma isotopic analysis.

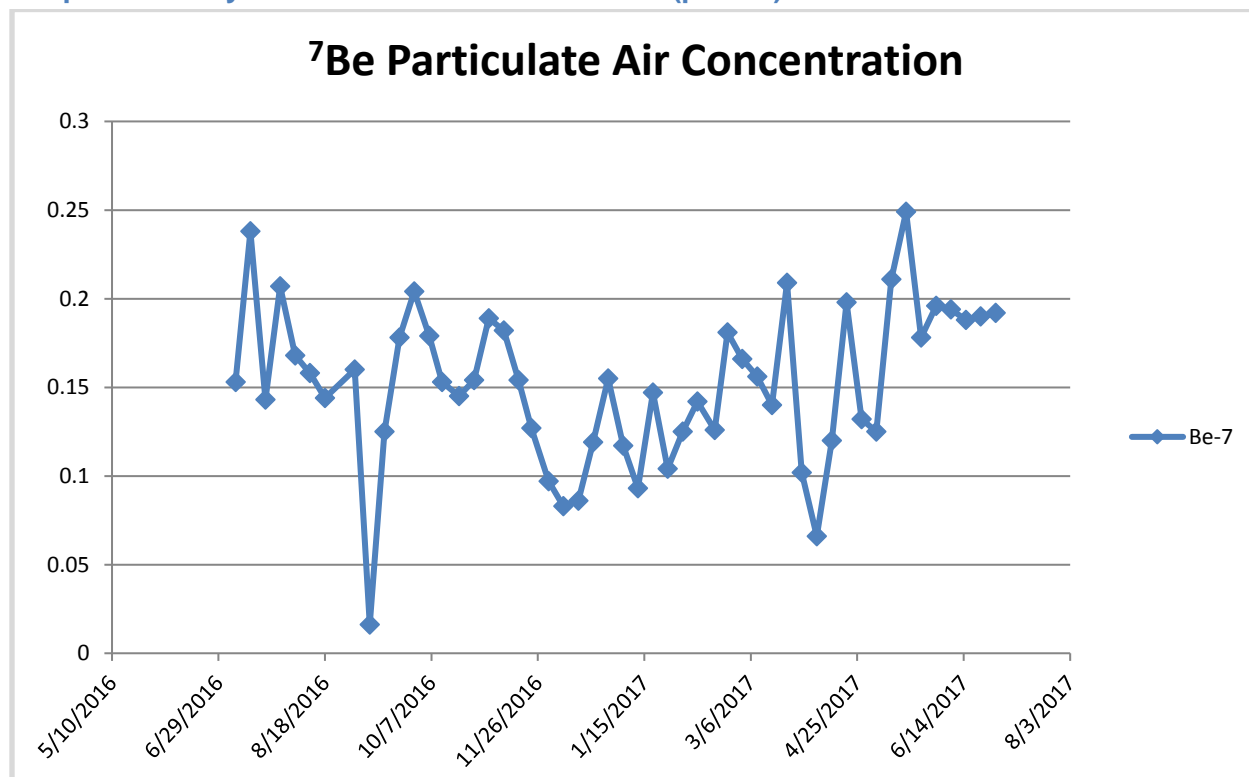
Gamma isotopic analysis was performed on two composite samples, one composed of the five particulate filters and the other of the five charcoal cartridges. Indication of  $^{131}\text{I}$  or any other fission or activation product requires gamma isotopic analysis of each individual particulate filter and associated charcoal cartridge.

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**Table 1: Weekly Air Particulate/Iodine Monitoring (pCi/m<sup>3</sup>)**

Number of Samples	Average <sup>7</sup> Be Concentration	Average Iodine Concentration
52	0.142 ± 0.031	<0.009

**Graph 1: Weekly Particulate <sup>7</sup>Be Concentration (pCi/m<sup>3</sup>)**



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## Airborne Pathway

### Soil

Four indicator, one control, and ten random annual soil samples were collected. Indicator soil samples were collected near Stringtown Cemetery, east of the CCL dam, at the CCL MUDS area, and at the public environmental education area. One control soil sample was collected east of WCGS at the Scott Valley Church. Random soil samples were collected at ten locations. Soil samples collected from the Coffey County public use areas are split with WCNOG.

A gamma isotopic analysis is performed on all soil samples collected.

**Table 2: Annual Samples for Radionuclide Deposition on Soil, pCi/kg KDHE (WCNOG)**

	<b>A-1</b>	<b>E-1</b>	<b>H-1</b>
<b>Nuclide</b>	<b>Near Stringtown Cemetery</b>	<b>Scott Valley Church (control)</b>	<b>East of CCL Dam</b>
<b>Date</b>	11/21/2016	3/21/2017	3/21/2017
<sup>137</sup> Cs	135 ± 22.9	234 ± 37.2	208 ± 26
<sup>40</sup> K	9890 ± 592	10200 ± 721	11300 ± 585
	<b>P-1 (MUDS)</b>	<b>R-1 (EEA)</b>	
<b>Date</b>	2/22/2017	5/17/2017	
<sup>137</sup> Cs	115 ± 27.7 (144.8 ± 26.5)	159 ± 23.2 (162.4 ± 34.3)	
<sup>40</sup> K	10800 ± 742 (9730.1 ± 623.0)	12500 ± 615 (12020.0 ± 787.8)	

**Table 3: Random Samples for Radionuclide Deposition on Soil (pCi/kg)**

<b>Location</b>	<b>Date</b>	<b>Nuclide</b>	
		<sup>137</sup> Cs	<sup>40</sup> K
Near 20th & Planter	10/3/2016	146 ± 24.6	10900 ± 694
23rd & Wayside	8/10/2016	237 ± 33.9	11300 ± 778
field near 19th & Homestead	10/24/2016	334 ± 43.5	10200 ± 711
near 13th & Wayside	11/8/2016	355 ± 38.8	7460 ± 580
field at 20th & Lynx	11/15/2016	189 ± 35.8	13100 ± 838
near 6th and Iris Rd	12/27/2016	<5.96	13700 ± 709
10th between Kafir & Juneberry	1/30/2017	205 ± 32.4	5400 ± 490
near 13th & Homestead	1/30/2017	147 ± 26.1	14000 ± 748
near 13th & Trefoil	1/24/2017	190 ± 31.4	8860 ± 659
near 23rd & Kafir Rd	5/2/2017	320 ± 31.6	12500 ± 670

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## Direct Radiation Pathway

### Direct Radiation Monitoring

Direct radiation monitoring was accomplished using Landauer Luxel optically stimulated luminescence dosimeters (OSLDs). OSLDs are read by Landauer. OSLD readings are corrected for transit and handling exposure.

Thirty-one locations around the WCGS were monitored by KDHE, including three control locations greater than ten miles from WCGS. Two OSLDs were used per site to generate an average quarterly reading. The dosimeters are contained in specially constructed holders suspended approximately one meter above the ground. Staff members exchange OSLDs quarterly. KDHE has collocated OSLDs with WCNOG at twelve sites.

**Table 4: Quarterly Direct Radiation Monitoring, mR/Standardized 90-day Qtr.**

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1. A-1 (1), North of WCGS	19.1	19.9	20.2	16.4
2. A-2, Sharpe	19.1	18.9	18.7	16.4
3. A-3, Forward Staging Area	17.6	17.9	18.7	15.4
4. B-1, East Sharpe	20.1	18.4	20.2	15.9
<b>5. B-2, Waverly Control</b>	19.6	18.9	19.7	16.9
6. C-1, near residence	19.1	18.4	18.7	16.9
7. D-1 (9), near residence	16.1	16.9	17.2	13.9
8. E-1, near residence	20.1	18.4	20.7	16.4
9. F-1, near residence	19.6	17.9	20.2	16.9
10. G-1 (14), WCNOG gate	20.1	18.4	19.2	18.4
11. H-0 (42), CCL baffle dike A	15.6	14.9	14.7	11.4
12. H-1, east of CCL dam	19.6	16.4	19.2	15.9
<b>13. H-2, LeRoy Control</b>	18.6	18.9	17.7	15.4
14. J-1, near residence	17.6	16.9	17.7	14.9
15. K-1 (29), near residence	15.6	15.9	15.7	14.4
16. L-1 (27), near residence	18.1	17.9	19.7	16.9
17. L-2, Burlington	17.6	18.4	19.2	15.4
18. L-3, Coffey County Shop	17.1	15.4	16.2	13.9
19. M-1 (26), near residence	18.1	17.4	16.2	13.9
20. N-1, near pasture	19.6	19.9	20.7	16.9
21. P-0 (43), CCL baffle dike B	14.6	14.9	13.7	11.4
22. P-1, New Strawn	19.1	18.4	19.7	15.9
<b>23. P-2, Hartford Control</b>	16.6	15.9	17.2	13.9
24. P-3, CCL entrance	19.6	18.4	21.2	16.9
25. P-4 (46), CCL near MUDS	18.1	17.9	20.2	14.4
26. P-5, JRR public use area	19.1	17.9	18.7	15.9
27. Q-1, near residence	17.6	17.9	19.2	17.4
28. R-0 (41), Stringtown cemetery	20.6	18.9	20.7	17.4
29. R-1 (37), near residence	18.1	17.4	19.2	16.4
30. R-2 (44), CCL EEA	20.1	17.4	18.7	15.4
31. R-3, near Coffey County Airport	19.6	18.9	19.7	15.9

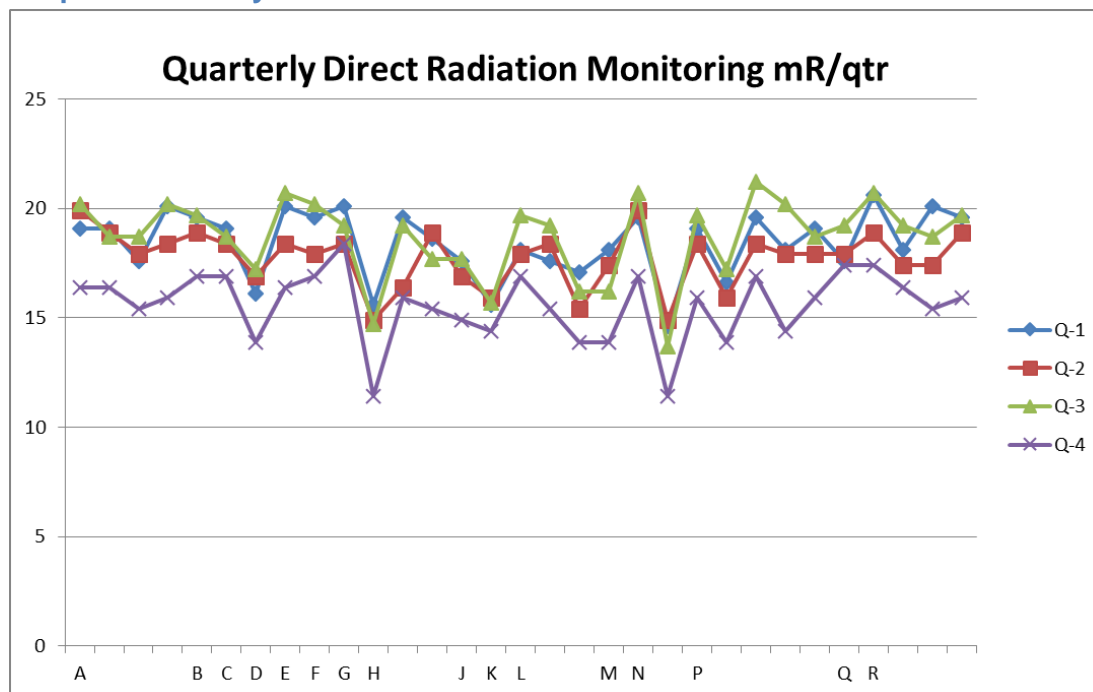
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**Table 5: Quarterly Collocated Direct Radiation Monitoring, mR/Standardized 90-day Qtr.**

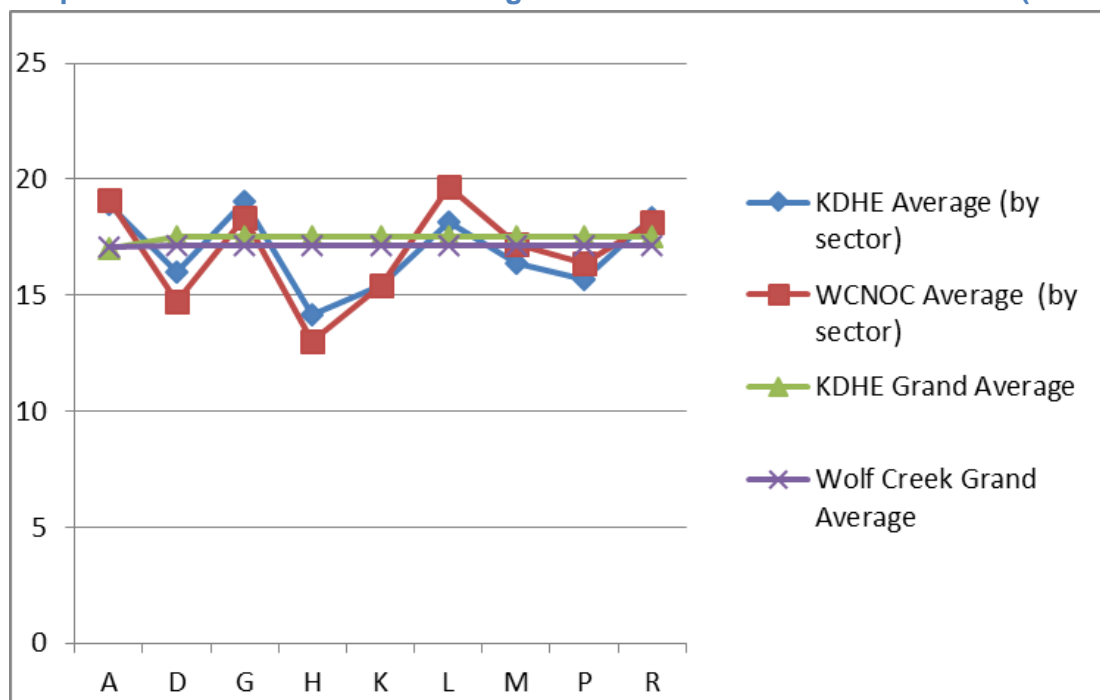
Location KDHE(WCNOC)	KDHE Monitoring Period	KDHE	WCNOC
1. A-1 (1)	7/8/2016-10/7/2016	19.1	19.4
	10/7/2016-1/4/2017	19.9	16.5
	1/4/2017-4/7/2017	20.2	18.4
	4/7/2017-7/5/2017	16.4	22.2
2. D-1 (9)	7/8/2016-10/7/2016	16.1	14.7
	10/7/2016-1/4/2017	16.9	14.6
	1/4/2017-4/7/2017	17.2	14.6
	4/7/2017-7/5/2017	13.9	15.0
3. G-1 (14)	7/8/2016-10/7/2016	20.1	17.2
	10/7/2016-1/4/2017	18.4	19.5
	1/4/2017-4/7/2017	19.2	16.5
	4/7/2017-7/5/2017	18.4	20.3
4. H-0 (42)	7/8/2016-10/7/2016	15.6	11.8
	10/7/2016-1/4/2017	14.9	11.6
	1/4/2017-4/7/2017	14.7	12.7
	4/7/2017-7/5/2017	11.4	16.0
5. K-1 (29)	7/8/2016-10/7/2016	15.6	13.3
	10/7/2016-1/4/2017	15.9	16.9
	1/4/2017-4/7/2017	15.7	15.6
	4/7/2017-7/5/2017	14.4	16.0
6. L-1 (27)	7/8/2016-10/7/2016	18.1	19.4
	10/7/2016-1/4/2017	17.9	19.3
	1/4/2017-4/7/2017	19.7	17.5
	4/7/2017-7/5/2017	16.9	22.6
7. M-1 (26)	7/8/2016-10/7/2016	18.1	16.5
	10/7/2016-1/4/2017	17.4	16.9
	1/4/2017-4/7/2017	16.2	15.3
	4/7/2017-7/5/2017	13.9	20.1
8. P-0 (43)	7/8/2016-10/7/2016	14.6	11.8
	10/7/2016-1/4/2017	14.9	13.7
	1/4/2017-4/7/2017	13.7	11.2
	4/7/2017-7/5/2017	11.4	15.0
9. P-4 (46)	7/8/2016-10/7/2016	18.1	17.9
	10/7/2016-1/4/2017	17.9	19.6
	1/4/2017-4/7/2017	20.2	20.0
	4/7/2017-7/5/2017	14.4	21.6
10. R-0 (41)	7/8/2016-10/7/2016	20.6	18.1
	10/7/2016-1/4/2017	18.9	17.0
	1/4/2017-4/7/2017	20.7	18.8
	4/7/2017-7/5/2017	17.4	20.6
11. R-1 (37)	7/8/2016-10/7/2016	18.1	17.4
	10/7/2016-1/4/2017	17.4	17.5
	1/4/2017-4/7/2017	19.2	18.5
	4/7/2017-7/5/2017	16.4	16.6
12. R-2 (44)	7/8/2016-10/7/2016	20.1	17.9
	10/7/2016-1/4/2017	17.4	19.0
	1/4/2017-4/7/2017	18.7	19.4
	4/7/2017-7/5/2017	15.4	17.1

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**Graph 2: Quarterly Direct Radiation Results for KDHE OSLD Sites**

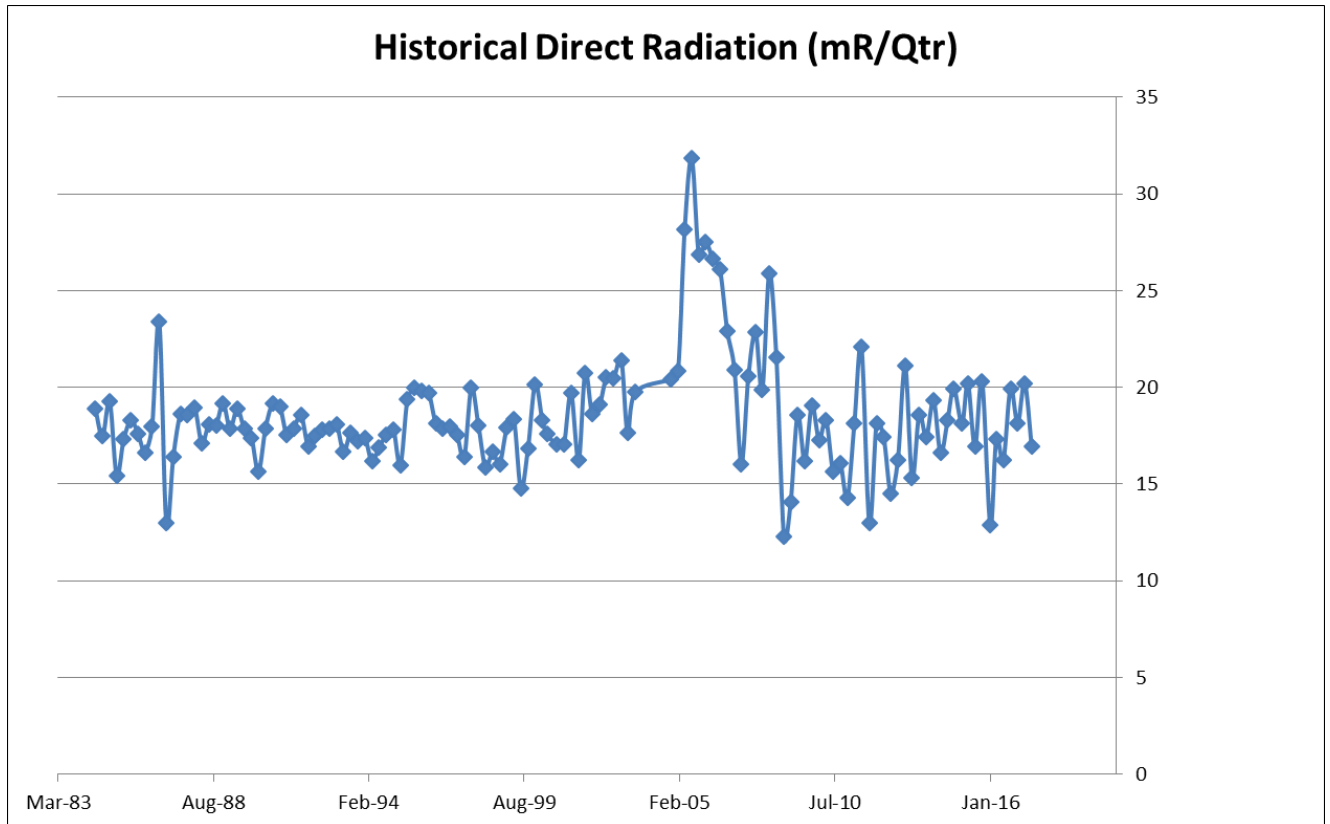


**Graph 3: Direct Radiation Monitoring Results for Co-located OSLD Sites (mR/Quarter)**



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**Graph 4: Historical KDHE Direct Radiation Monitoring Results (mR/Qtr)**





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## Waterborne Pathway

### Surface Water

Surface water sampling was accomplished through the collection of one-gallon grab samples at the indicated locations. A control sample was collected monthly from John Redmond Reservoir. One sample was collected monthly from the Coffey County Lake (CCL) at the spillway. One sample was collected monthly at the public fishing area on CCL, near the Makeup Discharge Structure (MUDS). Samples were collected monthly from the Neosho River near Leroy only when Coffey County Lake was overflowing to Wolf Creek at the spillway. Discharges to the river occurred during September & October of 2016 as well as April & May of 2017. A sample was also collected annually from the New Strawn City Lake.

Gamma isotopic and tritium ( $^3\text{H}$ ) analysis are done on each CCL and JRR water sample. Samples from John Redmond Reservoir and the Coffey County Lake Spillway were split with WCNOG.

**Table 6: Monthly Samples for Waterborne Radionuclides ( $^3\text{H}$ ) in Surface Water (pCi/L)**

CCL Spillway			John Redmond Reservoir (Control)			CCL MUDS				
Date		KDHE	WCNOC	Date		KDHE	WCNOC	Date		KDHE
7/19/2016		*	10513 ± 305	7/19/2016		*	<151	7/19/2016		*
8/17/2016		*	12300 ± 331	8/17/2016		*	<149	8/17/2016		*
9/13/2016		11253 ± 290	11912 ± 327	9/13/2016		<151	<149	9/13/2016		12764 ± 306
10/12/2016		11114 ± 289	11484 ± 322	10/12/2016		<149	<154	10/12/2016		10188 ± 278
11/30/2016		**	11339 ± 320	11/30/2016		**	<174	11/15/2016		10618 ± 284
12/27/2016		10452 ± 281	10910 ± 311	12/27/2016		<151	<143	12/8/2016		10580 ± 284
1/12/2017		10362 ± 280	10926 ± 295	1/12/2017		<152	<179	1/24/2017		9954 ± 276
2/8/2017		10452 ± 280	10758 ± 314	2/8/2017		<152	<156	2/8/2017		10580 ± 284
3/8/2017		10292 ± 279	10464 ± 311	3/8/2017		<151	<154	3/9/2017		10326 ± 280
4/12/2017		9510 ± 272	9231 ± 291	4/12/2017		<151	<144	4/12/2017		8067 ± 254
5/3/2017		8522 ± 261	8804 ± 283	5/3/2017		<153	<148	5/3/2017		8258 ± 256
6/8/2017		8337 ± 257	8178 ± 273	6/8/2017		<151	<153	6/22/2017		8459 ± 260
H-1 Neosho River Near Leroy										
			Date		KDHE					
			9/13/2016		<149					
			10/6/2016		<150					
			4/10/2017		<153					
			5/8/2017		<153					

\*lab did not receive sample in proper container for tritium analysis

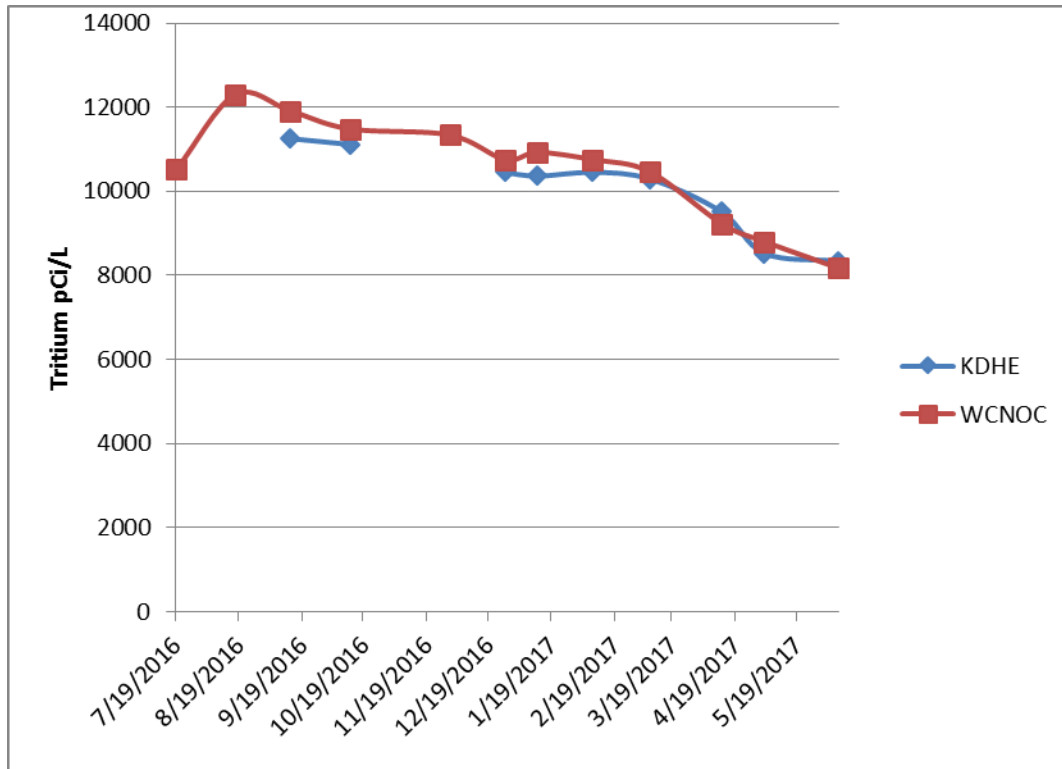
\*\*tritium sample container broke in transit, tritium analysis not completed

**Table 7: Annual Sample for Deposition of Airborne Radionuclides in Surface Water (pCi/L)**

New Strawn City Lake	
Date	$^3\text{H}$
4/24/2017	<153

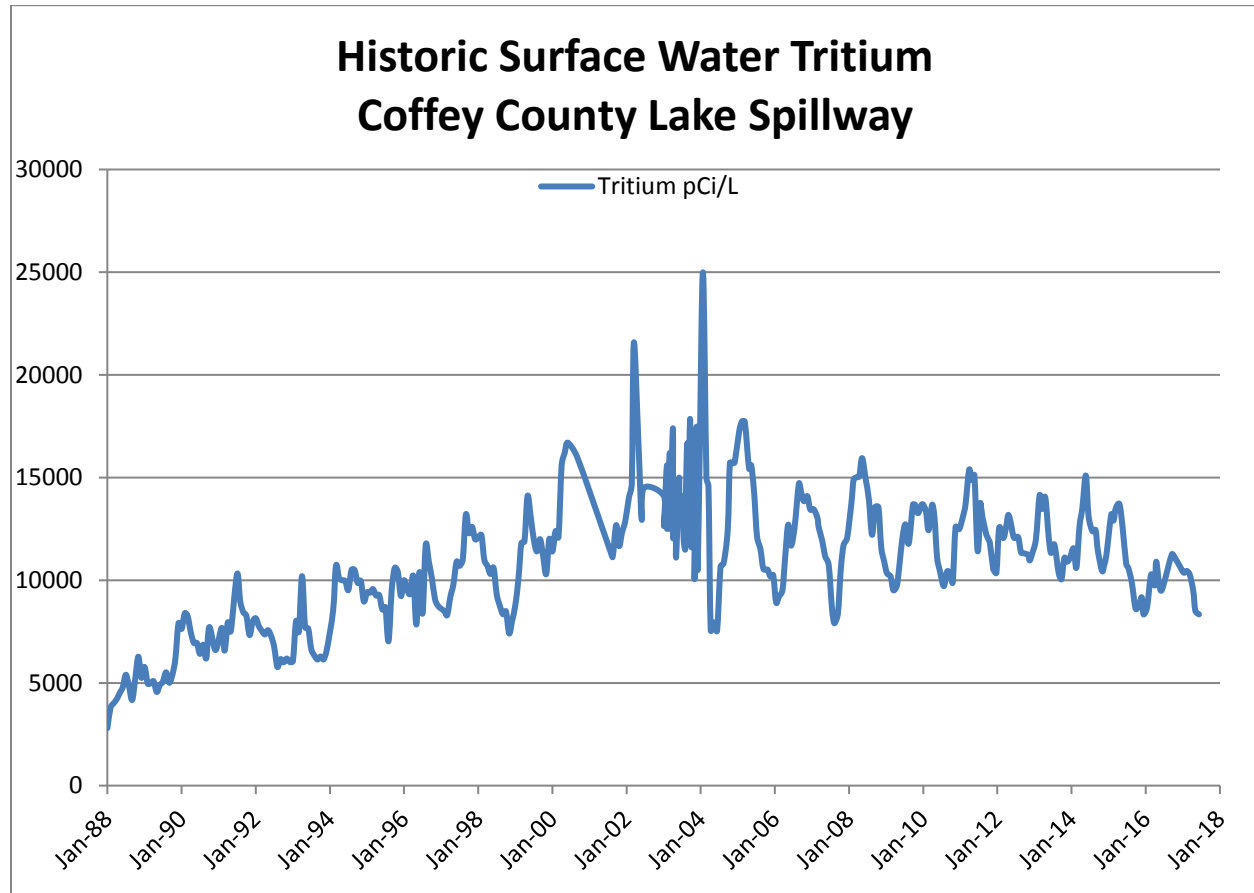
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Graph 5: Comparison of CCL Spillway Monthly Surface Water Tritium Results (pCi/L)



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Graph 6: Historical KDHE Surface Water Tritium Results (CCL Spillway)



### Ground Water

Ground water was collected quarterly offsite at wells in sectors B (control), N, L, F, G, and J. The control sample location was hydrologically up gradient from the facility and the other five are hydrologically down gradient. Samples were split with WCNOG. Samples were collected within the Wolf Creek owner controlled area along the Essential Service Water-buried pipe (two locations) and in the Wolf Creek protected area near the Auxiliary Building.

Gross alpha, beta, tritium and gamma isotopic analysis are done on each sample.

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**Table 8: Quarterly Samples for Waterborne Radionuclides in Ground Water (pCi/L) \*\*\***

Offsite Ground Water					
B-1 (B-12)			G-1 (G-2)		
Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG	Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG
8/24/2016	<152	<149	8/24/2016	<151	<149
11/30/2016	<152	<174	11/30/2016	<151	<174
2/8/2017	<151	<156	2/8/2017	<151	<156
5/3/2017	<152	<148	5/3/2017	<154	<148
F-1 (F-1)			C-2 (C-49)		
Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG	Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG
8/24/2016	<151	<149	8/24/2016	<153	<149
11/30/2016	<151	<174	11/30/2016	<151	<174
2/8/2017	<152	<156	2/8/2017	<152	<156
5/3/2017	<151	<148	5/3/2017	<151	<148
J-1 (J-2)			C-1 (C-10)		
Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG	Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG
8/24/2016	<153	<149	8/24/2016	<151	<149
11/30/2016	<151	<174	11/30/2016	<151	<174
2/8/2017	<153	<156	2/8/2017	<151	<156
5/3/2017	<151	<148	5/3/2017	<152	<148
Onsite Ground Water					
Auxiliary Building			EAST ESW-W		
Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG	Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG
8/10/2016	405 ± 105	509 ± 96	8/10/2016	210 ± 99	<165
			11/29/2016	*	<174
			2/13/2017	219 ± 99	<187
5/8/2017	470 ± 110	489 ± 95	5/8/2017	<152	<151
WEST ESW-W					
Date	<sup>3</sup> H KDHE	<sup>3</sup> H WCNOG			
8/10/2016	2416 ± 157	2529 ± 163			
11/29/2016	1608 ± 138	1700 ± 144			
2/13/2017	1281 ± 130	1316 ± 130			
5/8/2017	**	**			

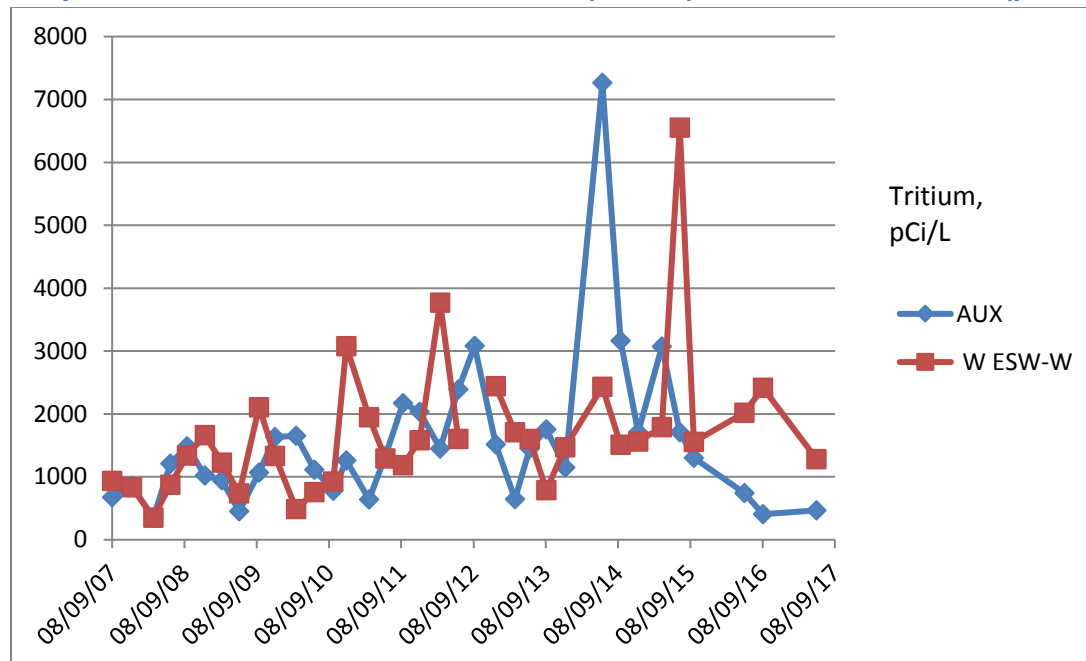
\*sample container broke in transit, tritium analysis not completed

\*\*WEST ESW-W was dry on 5/8/2017

\*\*\*KDHE samples collected on 8/17/16 were initially not screened for tritium and resampling took place 8/24/16. WCNOG samples collected on 8/17/16 and KDHE samples collected on 8/24/16

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**Graph 7: Historic Owner Controlled Area (Onsite) Groundwater Tritium (pCi/L)**



## Shoreline and Bottom Sediments

Shoreline sediment and bottom sediment were collected in the environment surrounding WCGS. Indicator bottom sediment samples were collected in the Coffey County Lake discharge cove, public environmental education area, and the CCL MUDS public access fishing area. A control sample of bottom sediment was obtained from John Redmond Reservoir. Indicator shoreline sediment was collected at the CCL discharge cove, the public environmental education area, and Wolf Creek off 11<sup>th</sup> St. A control sample of shoreline sediment was collected from JRR. Nine random bottom sediments were collected on CCL. Seven random shoreline sediments were collected on CCL and the Neosho River. The CCL and JRR samples are split with WCNO.

A gamma isotopic analysis is done on all sediment samples collected.

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**Table 9: Annual Samples for Waterborne Radionuclides in Sediments (pCi/kg dry)**

Location	Type	Date	<sup>137</sup> Cs	<sup>60</sup> Co	<sup>40</sup> K
			KDHE (WCNOC)	KDHE (WCNOC)	KDHE (WCNOC)
Wolf Creek	Shoreline	8/24/2016	25.4 ± 17.6	<7.17	9100
JRR	Bottom	10/27/2016	31.2 ± 15.4 (138.0 ± 77.6)	<8.97 (<29.5)	8190 ± 525 (17039 ± 1583)
CCL Discharge Cove	Shoreline	10/27/2016	104 ± 25.8 (120.1 ± 8.8)	<4.84 (<9.1)	12000 ± 695 (10437.0 ± 258.6)
JRR	Shoreline	10/27/2016	<8.17 (112.9 ± 59.3)	<3.34 (<53.5)	6480 ± 545 (16380.0 ± 1435)
CCL Discharge Cove	Bottom	10/27/2016	83.9 ± 16 (<55.6)	<7.06 (<36.4)	12400 ± 594 (12748 ± 1022)
JRR	Bottom	5/15/2017	125 ± 32.1 (<51.2)	<9.88 (<47.7)	18000 ± 1010 (18138 ± 1043)
CCL Discharge Cove	Bottom	5/15/2017	92.2 ± 25.8 (99.1 ± 53.7)	<10.5 (<32.4)	14000 ± 845 (10783.0 ± 1024)
JRR	Shoreline	5/15/2017	163 ± 24 (137.8 ± 28.8)	<7.30 (<19.2)	11400 ± 616 (10753.0 ± 691.8)
CCL Discharge Cove	Shoreline	5/15/2017	<3.79 (<26.8)	<4.11 (<19.6)	5600 ± 376 (5911.3 ± 551)
CCL MUDS	Bottom	2/22/2017	<9.5 (<16.8)	<7.98 (<18.3)	9130 ± 695 (9757.3 ± 627.2)
EEA	Bottom	10/26/2016	83.6 ± 28.1 (72.6 ± 31.4)	<8.60 (<24.9)	12900 ± 688 (12714.0 ± 751.3)
EEA	Shoreline	8/1/2016	119 ± 27.7 (96.9 ± 27.2)	<9.35 (<20.3)	11200 ± 738 (12465.0 ± 706.1)
Stringtown Cemetery	Shoreline	6/16/17	<4.51 (<16.7)	<2.57 (<16.9)	12200 ± 651 (11203.0 ± 684.5)

**Table 10: Random Samples for Waterborne Radionuclides in Sediments (pCi/kg dry)**

Date	Location	Type	<sup>60</sup> Co	<sup>137</sup> Cs
7/11/2016	Neosho River beside Planter Ln	Shoreline	<2.55	59.2 ± 25.4
10/18/2016	CCL Southeast End	Bottom	<7.39	60.7 ± 17.4
10/18/2016	CCL Southeast End	Bottom	<9.66	<11.5
10/18/2016	CCL Southeast End	Bottom	<6.93	22.2 ± 13.6
10/18/2016	CCL Southeast End	Bottom	<9.05	62.3 ± 21.9
10/18/2016	CCL Southwest End	Bottom	<2.88	<5.94
10/26/2016	Neosho River at 8 <sup>th</sup> Rd and Oxen	Shoreline	<10.5	<8.43
2/22/2017	Neosho River at LeRoy Bridge	Shoreline	<3.40	<3.89
3/21/2017	EEA Bird Observatory	Shoreline	<6.84	<5.80
3/21/2017	Black Bear Bosin Park	Shoreline	<2.66	<3.95
4/27/2017	East of Dam	Shoreline	<9.68	<11.6
6/5/2017	Midwest End CCL	Bottom	<7.86	<8
6/5/2017	East CCL	Bottom	<8.54	<7.57
6/5/2017	North End CCL	Bottom	<7.44	16.2 ± 11.4
6/5/2017	East CCL	Bottom	<8.54	<7.57
6/16/2017	Neosho River at Burlington Spillway	Shoreline	<5.41	<6.90

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## Aquatic Vegetation and Algae

Annual aquatic vegetation (algae and/or rooted) indicator samples were collected from the Coffey County Lake and Wolf Creek below the Coffey County Lake dam. Samples of aquatic vegetation were not able to be obtained from John Redmond Reservoir above the dam.

Gamma isotopic analysis is performed on all aquatic vegetation samples.

**Table 11: Annual Samples for Waterborne Radionuclides in Aquatic Vegetation KDHE, pCi/kg (dry) (WCNOC), pCi/kg (wet)**

Location	Sample Type	Date	<sup>40</sup> K	<sup>7</sup> Be
Wolf Creek	Arrowhead	8/24/2016	24900 ± 1650	1280 ± 297
CCL MUDS	American Pondweed	7/25/2016	8030 ± 1210 (2247.5 ± 273.7)	3780 ± 615 (705.3 ± 148.8)
CCL EEA	Primrose	8/1/2016	15000 ± 1640 (3155.9 ± 370.2)	2210 ± 419 (589.1 ± 182.7)
Stringtown Cemetery	Cattails	6/16/2017	6180 ± 476 (2588.8 ± 120.7)	1520 ± 179 (728.2 ± 60.4)

**Table 12: Random Samples for Waterborne Radionuclides in Aquatic Vegetation KDHE, pCi/kg**

Location	Sample Type	Date	<sup>40</sup> K	<sup>7</sup> Be
17 <sup>th</sup> Rd Bridge	American Lotus	7/11/2016	11900 ± 1530	<170
HWY 75 & 15 <sup>th</sup> Rd	Softrush	7/11/2016	9910 ± 1380	944 ± 454
27 <sup>th</sup> Between Oxen and Planter	Horsetail	7/25/2016	12700 ± 1160	1570 ± 302
Native beside Mathias Lake	Rose Mallow	8/15/2016	6600 ± 848	1080 ± 335
SE End of CCL	American Pondweed	10/18/2016	8830 ± 1100	812 ± 244
Mathias Lake	Duckweed	6/22/2017	30600 ± 2210	3520 ± 601

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## Ingestion Pathway

### Milk

Milk was sampled quarterly in Coffey County at two locations. Indicator samples were obtained from the Sunrise Dairy near Westphalia, KS. Control samples were obtained from Linsey Dairy near Lebo, KS. Each milk sample is analyzed for low levels of radioiodine and other gamma emitting nuclides. No gamma emitting nuclides attributable to Wolf Creek operation were detected in any milk sample.

**Table 13: Quarterly Samples for Radionuclides in Milk (pCi/L)**

Linsey Dairy			Sunrise Dairy		
Date	<sup>131</sup> I	<sup>40</sup> K	Date	<sup>131</sup> I	<sup>40</sup> K
8/18/2016	<0.622	1380 ± 69	9/26/2016	<0.314	1390 ± 63.7
10/26/2016	<0.269	1320 ± 66.4	12/21/2016	<0.443	1260 ± 62.8
3/2/2017	<0.399	1270 ± 67.4	3/9/2017	<0.700	1340 ± 73.9
5/11/2017	<0.758	1270 ± 67.6	6/15/2017	<0.820	1260 ± 77.8



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### Fish/Game Animals/Domestic Meat

Fish samples were collected from the Coffey County Lake and below John Redmond Reservoir on the Neosho River. Sample portions from fish collected in the Coffey County Lake and below John Redmond Reservoir on the Neosho River were split with WCNO. Fish collected at John Redmond Reservoir are used for control samples. Twenty-seven fish from a total of eleven species were sampled.

Game animal sampling is usually limited to the collection of edible meat portions from road-killed deer. Sample portions of road-killed deer are usually collected as available by WCNO and split with KDHE for laboratory analysis. One deer sample was obtained during SFY 2017.

A gamma isotopic analysis is done on all samples collected. Sample portions were edible.

**Table 14: Annual Samples for Radionuclides in Fish, pCi/kg, (wet)**

Location	Date	Type	<sup>3</sup> H KDHE (WCNO)	Gamma Activity
Coffey County Lake	11/2/2016	Blue Catfish Walleye White Bass Smallmouth Buffalo Channel Catfish	7260 ± 200 (8243 ± 248) NA (6601 ± 255) NA (7770 ± 238) NA (7364 ± 228) NA (7885 ± 241)	No Gamma Activity Above MDA was Detected in any Fish Sample
John Redmond Reservoir	10/17/2016	Smallmouth Buffalo Crappie Common Carp Bigmouth Buffalo Bass White Bass	NA (<131) NA (<135) NA (<135) NA (<135) NA (<133) NA (<133)	
Coffey County Lake	3/30//2017	Common Carp Freshwater Drum River Carpsucker White Bass Smallmouth Buffalo Channel Catfish	NA (4470 ± 179) NA (6691 ± 216) NA (4067 ± 176) NA (5125 ± 195) NA (5118 ± 196) 6640 ± 200 (6895 ± 226)	
John Redmond Reservoir	4/24/2017	Largemouth Bass Smallmouth Buffalo Bigmouth Buffalo Common Carp Blue Catfish White Crappie Freshwater Drum River Carpsucker Channel Catfish	<0.11 (<120) NA (<122) NA (<114) NA (<119) NA (<124) NA (<120) NA (<121) NA (<115) NA (<115)	

**Table 15: Random Samples for Radionuclides in Game (pCi/kg)**

Sample Location	Date	Sample Type	<sup>40</sup> K KDHE (WCNO)
Sector R, 2.0 Miles from Wolf Creek	10/31/2016	Roadkill Deer	3190 ± 245 (3336.7 ± 440.3)

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## Terrestrial Vegetation and Food Products

Terrestrial vegetation samples were taken at various locations around WCGS. This includes samples of crops grown throughout Coffey County and pasturage near WCGS. Samples collected on WCNOG property and samples of crops were split with WCNOG. A control sample was collected at Scott Valley Church approximately 6 miles from WCGS. Ten random samples were collected from locations around WCGS within the 50 mile zone.

A gamma isotopic analysis was done on each vegetation sample and edible portions of food products collected.

**Table 16: Annual Samples for Terrestrial Vegetation and Food Products (pCi/kg)**

Sample ID	Location	Sample Type	Date	<sup>40</sup> K KDHE (WCNOG)	<sup>7</sup> Be KDHE (WCNOG)
WCFV-1-H-157-3.1	East of Dam	Wildflowers	9/26/2016	11100 ± 1280	6650 ± 781.0
WCFV-1-E-087-5.8	Scott Valley Church (Control)	Corn	9/6/2016	3110 ± 242	<20.6
WCFV-1-P-289-1.6	MUDS	Pasturage	6/16/2017	4140 ± 386 (4695.2 ± 295.3)	1120.0 ± 157.0 (2319.4 ± 156.4)
NR-U1	4.5 mi. SSW of Wolf Creek	Irrigated Corn	10/12/2016	2430 ± 208 (2796.9 ± 239.6)	<5.90 (<56.4)
NR-D1	Coffey County	Irrigated Soybeans	10/19/2016	13500 ± 671 (15833 ± 545)	<29.7 (<127.3)
WCFV-1-A-005-2.5	Sharpe	Soybeans	11/8/2016	12000 ± 719	<28.7
NR-U1	4.5 mi. SSW of Wolf Creek	Irrigated Soybeans	10/19/2016	13500 ± 917 (13941 ± 505.5)	<32.5 (<98.1)
WCFV-1-R-330-2.9	EEA	Prairie Grass	5/17/2017	8060 ± 632 (6536.1 ± 425.4)	633 ± 155 (493.1 ± 155.1)
NR-D2	11.5 mi S of Wolf Creek	Irrigated Corn	10/10/2016	2740 ± 267 (3077.8 ± 270.7)	<21.0 (<73.7)

**Table 17: Random Samples for Vegetation and Food Products (pCi/kg)**

Location	Sample Type	Date	<sup>40</sup> K	<sup>7</sup> Be
20 <sup>th</sup> Between Verdure and Wayside	Red Milo	9/15/2016	3470 ± 852	<809
Near 8 <sup>th</sup> and Reaper	Red Milo	9/20/2016	<446	1060 ± 308
Near 12 <sup>th</sup> & Juniper	Corn	9/20/2016	2940 ± 237	<13.9
16 <sup>th</sup> & Reaper	Corn	10/3/2016	2450 ± 219	<22.4
Field Near 15 <sup>th</sup> & Trefoil	Soybeans	10/24/2016	15300 ± 1060	1780 ± 248
Field Near 8 <sup>th</sup> & Verdure	Soybeans	10/24/2016	12900 ± 687	<37.8
Oxen Lane & Wolf Creek Crossing	Soybeans	10/26/2016	12800 ± 886	<52.3
Field Near 16 <sup>th</sup> & Wayside	Turnips	11/8/2016	3030 ± 359	343.0 ± 90.6
Field Near Trefoil & 16 <sup>th</sup>	Wheat	6/16/2017	2850 ± 349	2190 ± 238
20 <sup>th</sup> Between Wayside and Verdure	Winter Rye	6/22/2017	2770 ± 473	4490 ± 447

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## Radiochemistry Laboratory

In September of 2015, the KDHE Radiochemistry Laboratory was closed and further sample analysis was performed by the Iowa State Hygienic Laboratory (ISHL) at the University of Iowa. The KDHE Radiochemistry lab did not analyze any samples for SFY 2017 though they were in charge of shipping samples to ISHL until September 2017. Quality assurance is shown for both the KDHE Radiochemistry Lab as well as ISHL until as such a time that the KDHE Radiochemistry Laboratory is permanently decommissioned.

### KDHE Radiochemistry Laboratory

#### Quality Assurance

The KDHE Radiation Laboratory has an established internal Quality Assurance program. Quality Control elements include routine calibrations and performance checks on counting equipment and participation in an environmental radioactivity laboratory intercomparison studies program. This program is currently accomplished with blind samples purchased from Environmental Resource Associates. Results for SFY 2015 are presented in Table 18, intercomparison studies were not completed for 2016 due to the closing of the laboratory early in the fiscal year.

#### Equipment

The following is a description of the equipment used by the KHEL Radiochemistry laboratory.

##### Multichannel gamma-spectrometer

Gamma radiation is measured spectra determined with a Canberra Genie-2000 Multichannel Analyzer (MCA) system. Detectors available are three high purity germanium detectors (efficiencies – 20 % - 40%) and one germanium-lithium (GeLi) Detector (efficiency 20%).

##### Low background alpha/beta system

Low background alpha/beta gas-flow internal proportional counters – one Tennelec LB5100, one Oxford Series 5XLB, one Tennelec LB4000 multi-detector and one Canberra 2201.

##### Internal proportional counter (IPC)

Gross alpha and radium analyses are performed with windowless gas-flow internal proportional counters – four Protean MPC 2000 and two NMC PC5.

##### Liquid scintillation

Analysis for tritium in water is performed using a one Wallac 1409 and one PE Tri-Carb 3100 TR.

##### Miscellaneous equipment

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The Radiochemistry Section has various devices used for special purposes. A Ludlum Model 2200 single channel analyzer is used with a radon flask scintillation counter for radon and radium analyses. Another Ludlum Model 2200 single channel analyzer is used with a halogen quenched GM pancake probe for routine monitoring of personnel and incoming samples.

**Table 18: KDHE Radiochemistry Laboratory ERA Intercomparison Studies**

Analyte	Analysis Date	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation
<b>Barium-133</b>	7/11/2014	pCi/L	61.8	68.7	57.3-75.6	Acceptable
	10/8/2014	pCi/L	38.6	49.1	40.3-54.5	Not Acceptable
	1/12/2015	pCi/L	57.0	67.6	56.4-74.4	Acceptable
	4/8/2015	pCi/L	77.3	82.5	69.3-90.8	Acceptable
<b>Cesium-134</b>	7/11/2014	pCi/L	65.9	72.3	59.0-79.5	Acceptable
	10/8/2014	pCi/L	72.3	89.8	73.7-98.8	Not Acceptable
	1/12/2015	pCi/L	118	124	112-139	Acceptable
	4/8/2015	pCi/L	69.6	75.7	61.8-83.3	Acceptable
<b>Cesium-137</b>	7/11/2014	pCi/L	171	163	147-181	Acceptable
	10/8/2014	pCi/L	84.9	98.8	88.9-111	Not Acceptable
	1/12/2015	pCi/L	118	124	112-139	Acceptable
	4/8/2015	pCi/L	198	189	170-210	Acceptable
<b>Cobalt-60</b>	7/11/2014	pCi/L	79.9	75.5	68.0-85.5	Acceptable
	10/8/2014	pCi/L	77.2	92.1	82.9-104	Not Acceptable
	1/12/2015	pCi/L	58.0	62.4	56.2-71.2	Acceptable
	4/8/2015	pCi/L	85.3	84.5	76.0-95.3	Acceptable
<b>Gross Alpha</b>	7/23/2014	pCi/L	53.4	45.4	23.6-57.4	Acceptable
	1/23/2015	pCi/L	61.2	62.3	32.6-77.3	Acceptable
	5/14/2015	pCi/L	44.0	42.6	22.1-64.0	Acceptable
<b>Gross Beta</b>	8/9/2014	pCi/L	36.0	33.4	21.7-41.1	Acceptable
	1/29/2015	pCi/L	40.1	48.9	33.1-56.0	Acceptable
	4/16/2015	pCi/L	43.3	32.9	21.3-40.6	Not Acceptable
<b>Tritium</b>	7/11/2014	pCi/L	10800	11200	9750-12300	Acceptable
	11/15/2014	pCi/L	6920	6880	5940-7570	Acceptable
	1/9/2015	pCi/L	10500	10600	9220-11700	Acceptable
	5/17/2015	pCi/L	3700	3280	2770-3620	Not Acceptable
<b>Iodine-131</b>	7/11/2014	pCi/L	24.2	26.1	21.7-30.8	Acceptable
	1/7/2015	pCi/L	22.5	22.3	18.5-26.6	Acceptable
	4/8/2015	pCi/L	24.8	23.8	19.7-28.3	Acceptable
<b>Strontium-89</b>	7/11/2014	pCi/L	45.2	42.7	32.9-49.8	Acceptable
	1/13/2015	pCi/L	46.9	52.1	41.2-59.6	Acceptable
	4/17/2015	pCi/L	67.2	63.2	51.1-71.2	Acceptable
<b>Strontium-90</b>	7/11/2014	pCi/L	30.0	31.7	23.1-36.7	Acceptable
	1/27/2015	pCi/L	27.7	32.4	23.7-37.5	Acceptable
	4/17/2015	pCi/L	37.3	41.9	30.8-48.1	Acceptable
<b>Zinc-65</b>	7/11/2014	pCi/L	90.0	82.0	73.8-98.5	Acceptable
	10/8/2014	pCi/L	276	310	279-362	Not Acceptable
	1/12/2015	pCi/L	99.2	98.7	88.8-118	Acceptable
	4/8/2015	pCi/L	224	203	183-238	Acceptable

<sup>1</sup> The KDHE radiochemistry laboratory, under certification of the Environmental Protection Agency is required to pass one PT study for certified analytes per year, and participates in extra PT studies throughout the year as additional Quality Assurance checks.

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**Table 19: KDHE Radiochemistry Laboratory Method Detection Limits**

<b>GeLi [HPGe] detection system <sup>a</sup></b>						
Environmental Sampling						
	Water and Milk	Filter	Wipe	Soil and Sediment	Biota	Vegetation and Food Products
Minimum sample size	2000 ml	1500 m <sup>3</sup>	Total	0.45 kg	0.3 kg	1 kg
Minimum Counting Time	8 hr.	3 hr	3 hr.	15 hr.	15 hr.	15 hr.
Method Detection Limit	pCi/L	pCi/m <sup>3</sup>	pCi/wipe	pCi/kg-dry	pCi/kg-wet	pCi/kg-dry
<sup>7</sup> Be	64[22]	0.03 [0.02]	N/A	346 [186]	231 [144]	35[19]
<sup>40</sup> K	88 [39]	0.03 [0.02]	N/A	828 [654]	459 [262]	360 [72]
<sup>51</sup> Cr	52 [32]	0.01 [0.009]	5 [3]	35 [22]	41 [32]	55 [46]
<sup>54</sup> Mn	4 [2]	0.004 [0.003]	1 [0.7]	7 [11]	30 [15]	51 [24]
<sup>58</sup> Co	4 [2]	0.008 [0.002]	2 [1]	11 [23]	37 [20]	60 [36]
<sup>59</sup> Fe	8 [3]	0.01 [0.01]	3 [2]	22 [16]	41 [15]	107 [52]
<sup>60</sup> Co	11 [7]	0.01 [0.0053]	2.5 [1.7]	11 [35]	43 [26]	56 [50]
<sup>65</sup> Zn	8 [4]	0.01 [0.007]	N/A	48 [30]	38 [22]	125 [63]
<sup>95</sup> Nb	7 [3]	0.009 [0.007]	2.5 [1.4]	13 [30]	44 [26]	48 [4]
<sup>95</sup> Zr	6 [3]	0.01 [0.002]	0.5 [0.3]	20 [27]	27 [19]	86 [54]
<sup>99</sup> Mo	5 [3]	0.002 [0.0014]	1 [0.6]	83 [43]	33 [21]	****
<sup>103</sup> Ru	10 [7]	0.004 [0.003]	N/A	10 [20]	29 [21]	44 [47]
<sup>106</sup> Ru	55 [43]	0.07 [0.05]	1.5 [1]	100 [192]	43 [29]	46 [65]
<sup>110m</sup> Ag	4 [3]	0.006 [0.0002]	N/A	47 [33]	47 [34]	86 [55]
<sup>125</sup> Sb	35 [12]	0.02 [0.01]	N/A	30 [44]	96 [51]	126 [6]
<sup>131</sup> I	5 [3] (1) <sup>b</sup>	0.00027 [0.00027] <sup>c</sup>	1.5 [1]	10 [20]	37 [23]	45 [13]

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<sup>134</sup> Cs	5 [3]	0.007 [0.004]	1.4 [1]	14 [29]	37 [24]	57 [39]
<sup>137</sup> Cs	7 [4]	0.006 [0.004]	1 [0.3]	11 [29]	32 [21]	52 [56]
<sup>140</sup> Ba	10 [6]	0.004 [0.003]	N/A	36 [17]	24 [15]	157 [39]
<sup>140</sup> La	9 [5]	0.01 [0.02]	N/A	12 [9]	34 [21]	47 [6]
<sup>141</sup> Ce	8 [3]	0.002 [0.001]	N/A	19 [23]	22 [13]	63 [3]
<sup>144</sup> Ce	35 [14]	0.013 [0.0096]	N/A	96 [103]	110 [70]	267 [14]
<sup>226</sup> Ra	116 [69]	0.05 [0.03]	N/A	828 [654]	323 [195]	858 [51]
<sup>228</sup> Ac	30 [18] 15 h	0.0127 [0.0099]	N/A	68 [33]	146 [87]	27 [12]
<sup>228</sup> Th	387 [142]	0.09 [0.06]	N/A	859 [317]	944 [356]	2100 [167]
<sup>234</sup> Th	618 [87] 15 h	0.159 [0.0423]	N/A	1009 [378]	1300 [556]	570 [94]
<sup>235</sup> U	N/A	N/A	45 [30] 15 h	N/A	N/A	N/A
<sup>239</sup> Np	41 [33]	0.01 [0.009]	5 [3]	64 [44]	40 [30]	97 [71]

<sup>a</sup> GeLi = Germanium lithium; HPGe = High purity germanium.

<sup>b</sup> Two methods of analysis are done: **1)** 8 hour direct gamma isotopic analysis of a 2000 mP milk or water sample that has a method detection limit (MDL) of 3 pCi/P, and **2)** 3 hour gamma isotopic analysis of ion exchange resin after a 1500 mP milk sample is filtered through an ion exchange column that has an MDL of 1 pCi/P.

<sup>c</sup> The MDL for <sup>131</sup>I when analyzing a charcoal cartridge is 0.03 [0.02] pCi/m<sup>3</sup> based upon a 250 m<sup>3</sup> sample volume. If the sample volume is increased to 1500 m<sup>3</sup>, the MDL is 0.002 [0.001] pCi/m<sup>3</sup>.

Method detection limits of present analytical methods for selected radionuclides monitored by the KHEL Radiochemistry Laboratory. These limits are intended as guides to order of magnitude sensitivities and are calculated with a 95% level of confidence (activity will be detected 95% of the time if it is present).

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## Iowa State Hygienic Laboratory (ISHL)

### Quality Assurance

The State Hygienic Laboratory at the University of Iowa (SHL) Radiation Laboratory has an established internal Quality Assurance program. Quality Control elements include routine calibrations and performance checks on counting equipment and participation in an environmental radioactivity laboratory intercomparison studies program. This program is currently accomplished with blind samples purchased from Environmental Resource Associates. Results for SFY 2016 are presented in Table 20.

### Equipment

The following is a description of the equipment used by the State Hygienic Laboratory at the University of Iowa Radiation Laboratory.

#### Gamma Spectrophotometry

Gamma radiation is measured utilizing two High Purity Germanium Detectors (18% & 35% efficient) connected to DSP<sup>EC</sup> jr 2.0 digital signal processors and ORTEC Maestro Multi Channel Analyzer (MCA) emulation software. Spectra are analyzed using GammaVision gamma spectroscopy software.

#### Alpha/Beta Counting

Analyses for gross Alpha/Beta, radium-226/228, and strontium-89/90 are performed utilizing two Canberra LB4200 Multi-Detector Low Background Alpha/Beta Counting Systems, including 24 total detectors.

#### Liquid Scintillation Counting

Analyses for tritium, radon-222, and surface contamination are performed utilizing two liquid scintillation counters, one Packard TriCarb 2550TR and one Beckman LS6500.

#### Alpha Spectrometry

Analyses for isotopic uranium, thorium, plutonium, and other alpha emitting radionuclides are performed utilizing two alpha spectrometry systems, one ORTEC Alpha Ensemble and one ORTEC OctètePLUS, including 12 total detectors.

#### Miscellaneous equipment

SHL's Radiation Laboratory also possesses a number of handheld Geiger-Muller counters for contamination surveys and incoming sample screening, as well as sample processing equipment, including drying ovens, muffle furnaces, and ball mills, for preparing solid samples for analysis.

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**Table 20: ISHL Radiochemistry Laboratory ERA Intercomparison Studies**

Analyte	Analysis Date	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation
Barium-133	7/22/2016	pCi/L	80.3	82.9	69.7-91.2	Acceptable
	1/27/2017	pCi/L	85.1	85.6	72.0-94.2	Acceptable
Cesium-134	7/22/2016	pCi/L	61.8	65.3	53.1-71.8	Acceptable
	1/27/2017	pCi/L	50.9	52.6	42.4-57.9	Acceptable
Cesium-137	7/22/2016	pCi/L	96.6	95.2	85.7-107	Acceptable
	1/27/2017	pCi/L	114	112	102-126	Acceptable
Cobalt-60	7/22/2016	pCi/L	116	117	105-131	Acceptable
	1/27/2017	pCi/L	110	113	102-126	Acceptable
Gross Alpha	7/29/2016	pCi/L	39.5	48.1	25.0-60.5	Acceptable
	1/20/2017	pCi/L	44.3	52.3	27.3-65.5	Acceptable
Gross Beta	7/27/2016	pCi/L	24.5	28.6	18.2-36.4	Acceptable
	1/17/2017	pCi/L	32.3	41.6	27.7-49.0	Acceptable
Tritium	7/18/2016	pCi/L	12500	12400	10800-13600	Acceptable
	1/13/2017	pCi/L	12000	12500	10900-13800	Acceptable
Strontium-89	8/2/2016	pCi/L	55.7	53.3	42.3-60.9	Acceptable
	1/30/2017	pCi/L	56.6	55.5	44.3-63.2	Acceptable
Strontium-90	8/2/2016	pCi/L	35.3	39.2	28.8-45.1	Acceptable
	1/30/2017	pCi/L	40.3	43.1	31.8-49.5	Acceptable
Zinc-65	7/22/2016	pCi/L	123	113	102-134	Acceptable
	1/27/2017	pCi/L	212	189	170-222	Acceptable



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**Table 20: ISHL Radiochemistry Laboratory Method Detection Limits**

Gamma Spectrometry Detection Limits								
Matrix	Filter	Cartridge	Wipe	Soil & Sediment	Milk	Water	Vegetation	Biota
Minimum Sample Size	1500m <sup>3</sup>	1500m <sup>3</sup>	N/A	600 g	3000 mL	1000 mL	500 g	500 g
Minimum Count Time	3 hours	16 hours	3 hours	3 hours	3 hours	6 hours	4 hours	4 hours
Units	pCi/m <sup>3</sup>	pCi/m <sup>3</sup>	pCi	pCi/kg dry	pCi/L	pCi/L	pCi/kg dry	pCi/kg wet
Be-7	0.0090	-	14	59	4.0	13	120	9.2
K-40	0.0050	-	7.5	60	5.0	22	190	38
Am-241	0.0010	-	1.5	27	2.6	6.2	-	12
Mn-54	0.0003	-	0.5	5.9	0.4	2.4	4.5	1.6
Co-57	0.0005	-	0.8	6.2	0.4	1.3	12	2.4
Co-58	0.0004	-	0.6	5.9	-	-	3.1	2.3
Fe-59	0.0007	-	1.1	17	0.4	3.7	7.2	1.5
Co-60	0.0004	-	0.6	7.2	0.9	1.2	15	3.2
Zn-65	0.0008	-	1.2	-	0.5	1.9	36	1.7
Kr-85	0.1130	-	170	-	-	-	-	-
Sr-85	0.0005	-	0.8	-	-	-	-	-
Rb-86	0.0040	-	6.0	-	-	-	-	-
Sr-87m	0.0008	-	1.2	-	-	-	-	-
Kr-88	0.0030	-	4.5	-	-	-	-	-
Y-88	0.0006	-	0.9	-	-	-	-	-
Y-91	0.1430	-	220	-	-	-	-	-
Nb-95	0.0003	-	0.5	4.3	0.5	1.5	6.6	0.9
Zr-95	0.0007	-	1.1	-	0.5	3.2	11	6.8
Zr-97	0.0180	-	27	-	-	-	-	-
Mo-99	0.0020	-	3.0	58	2.7	4.0	-	16
Tc-99m	0.0003	-	0.5	-	0.5	1.5	6.7	-
Ru-103	0.0010	-	1.5	6.7	0.4	0.4	14	2.1
Rh-105	0.0010	-	1.5	-	-	-	-	-
Ru-106	0.0050	-	7.5	25	4.9	5.7	150	23
Ag-110m	0.0003	-	0.5	7.2	0.5	1.8	17	2.9
In-111	0.0004	-	0.6	4.9	0.2	1.0	-	1.8
I-123	0.0007	-	1.1	-	0.6	0.8	15	2.6
Sb-125	0.0009	-	1.4	11	1.5	4.8	22	5.6
Sb-127	0.0007	-	1.1	-	-	-	-	-

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I-131	0.0004	0.0063	0.6	6.8	0.3	1.1	4.3	0.9
I-132	0.0009	-	1.4	2.5	0.4	0.9	-	1.0
I-133	0.0010	-	1.5	6.1	0.5	1.9	6.2	2.2
Cs-134	0.0004	-	0.6	5.6	0.4	0.5	3.4	3.3
Cs-136	0.0004	-	0.6	6.8	0.5	1.8	4.4	2.8
Cs-137	0.0009	-	1.4	6.8	0.5	1.7	7.4	3.9
Ba-140	0.0030	-	4.5	22	2.1	2.3	25	8.0
La-140	0.0006	-	0.9	1.5	0.3	0.7	8.4	1.2
Ce-141	0.0006	-	0.9	8.2	0.6	1.2	16	1.8
Ce-143	0.0010	-	1.5	7.1	-	-	27	4.1
Ce-144	0.0040	-	6.0	46	3.4	9.1	92	15
Nd-147	0.0010	-	1.5	12	0.9	5.2	-	-
Yb-169	0.0030	-	4.5	-	1.1	2.9	-	-
Bi-212	0.0390	-	59	98	-	-	560	-
Pb-212	0.0040	-	6.0	12	-	-	17	-
Bi-214	0.0030	-	4.5	15	-	-	36	-
Pb-214	0.0030	-	4.5	28	-	-	69	-
Ra-224	0.0170	-	26	190	-	-	-	-
Ac-228	0.0030	-	4.5	28	1.9	7.6	-	-
Th-228	0.0560	-	84	630	45.6	110.0	910	220
Np-239	0.0030	-	4.5	24	1.9	5.0	27	5.7

All MDAs are reported as activity at time of count.

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**Table 21: ISHL Radiochemistry Laboratory Individual Analyte Detection Limits (A)**

Analyte	Tritium		Gross Alpha				Gross Beta			
Matrix	Water & Urine	Tissue	Water	Soil & Sediment	Filter	Wipe	Water	Soil & Sediment	Filter	Wipe
Requested Sample Size	50 mL	30 g	100 mL	0.1 g	250 m3	N/A	100 mL	0.1 g	250 m3	N/A
Minimum Counting Time	100 min	100 min	500 min	500 min	100 min	100 min	500 min	500 min	100 min	100 min
Minimum Detection Limit	300 pCi/L	300 pCi/g wet	3.0 pCi/L	5000 pCi/kg dry	0.002 pCi/m3	0.4 pCi	4.0 pCi/L	3000 pCi/kg dry	0.002 pCi/m3	0.4 pCi
Counting Methodology	LSC	LSC	GPC	GPC	GPC	GPC	GPC	GPC	GPC	GPC

**Table 22: ISHL Radiochemistry Laboratory Individual Analyte Detection Limits (B)**

Analyte	Radon-222	Radium-226		Radium-228		Strontium-89	Strontium-90	Iodine-131
Matrix	Water	Water	Soil & Sediment	Water	Soil & Sediment	Water/Milk	Water/Milk	Water/Milk
Requested Sample Size	40 mL	1000 mL	600 g	1000 mL	600 g	1000 mL	1000 mL	3000 mL
Minimum Counting Time	50 min	60 min	180 min	60 min	180 min	60 min	60 min	180 min
Minimum Detection Limit	20 pCi/L	1 pCi/L	20 pCi/kg dry	1 pCi/L	40 pCi/kg dry	10 pCi/L	2 pCi/L	1 pCi/L
Counting Methodology	LSC	GPC	Gamma	GPC	Gamma	GPC	GPC	Gamma